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Site Map

Lesson 2 (further reading)

By the completion of this lesson you should be able to:

- Make calculations using the relationship **Uout=A (U2 - U1)**
- Design and assemble simple Op. Amp as a differential amplifier/ comparator and explain their function and practical application

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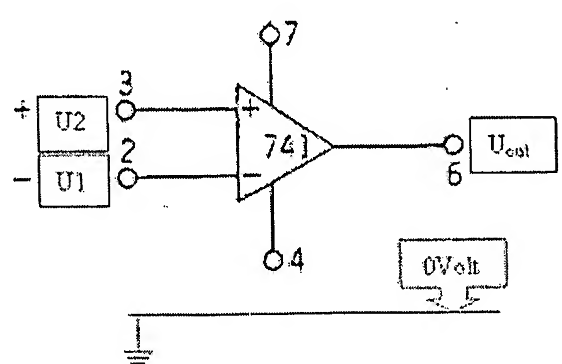
CONNECTION OF OPERATIONAL AMPLIFIER AS A COMPARATOR (DIFFERENTIAL AMPLIFIER)

Connection - operation

As already has been reported the operational amplifier is used in the digital circuits as a comparator (comparator). Comparator is named in the technology of digital electronic circuit for it compares two inputs (or numbers) and locates the input (or the number) that has the biggest value.



The circuit of comparator that uses the op-amp μA741 appears in the diagram on the right. This has the possibility to shape the value of the voltage in the output (Uout) on leg 6, by comparing the values of voltages (U2 and U1) that are applied on the legs 3 and 2.

The op-amp in comparator connection functions basically also as differential amplifier because it amplifies simultaneously also the difference of potential (voltage) between two inputs, namely U2 and U1. The result in the output Uout is

proportional to this difference and is given by the below fundamental relationship of op-amp:

Uout = A (U2 - U1) or Uout = A Uin (1)

Where:

Uout: Voltage in the output op-amp (difference of potential the leg 6 and the end of 0V)

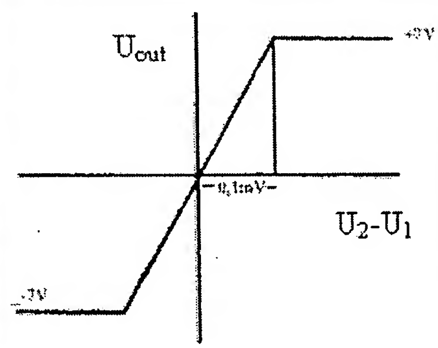
U2: The voltage in the not inversion input of op-amp (difference of potential between the leg 3 and the end of 0V)

U1: The voltage in the inverted input of op-amp (difference of potential between the leg 2 and the end of 0V)

A: Gain factor of the op-amp (that is around 100,000)

Uin: The difference of voltages U2 - U 1:

Supply legs 7 (+ Vs) and 4 (Vs) in the circuits of comparator, can be linked, as already I have reported, in single supply (e.g. Vs = + 9 V and -Vs = 0 V) as long as in double supply (e.g. Vs = + 9 V and - Vs = -9 V).



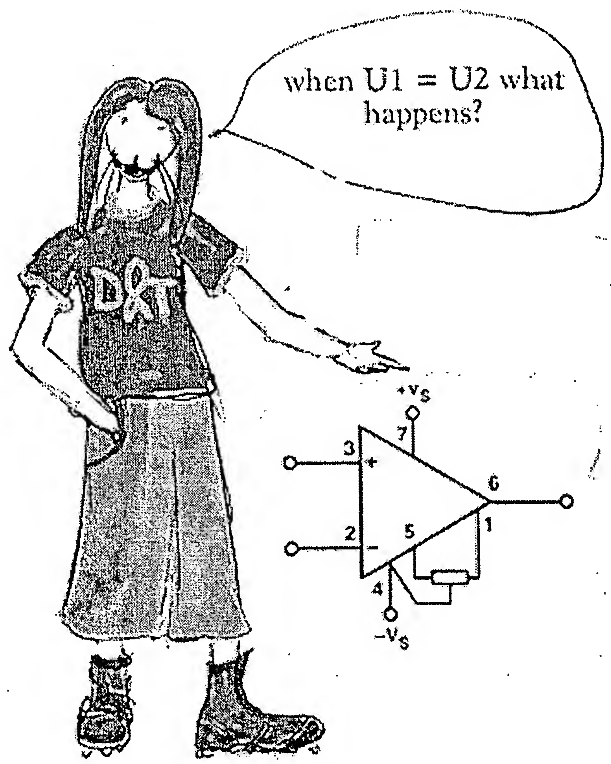
The relation (1) shows that the output voltage Uout is proportional to the difference of the input voltages. This relation however is in effect only for very small values of the difference U 2 - U 1 (roughly 0,1 mV). This is owed in the big value of the gain factor A of the op-amp, that it has as a result the amplifier be led immediately to saturation with a small difference in U2 - U1 and the output Uout takes practicallyvalues that are close to the values of supply of μA741 (see graph). Thus we have the below results depending on the type of supply of μA741:

DOUBLE SUPPLY (+9V, -9V)	SINGLE SUPPLY (+9V, -0V)
• If U2 > U1 then Uout HIGH (Uout is about +7V) • If U2 < U1 then Uout LOW (Uout is about -7V)	• If U2 > U1 then Uout HIGH (Uout is about +7V) • If U2 < U1 then Uout LOW (Uout is about +2V)

The important conclusion that comes out from the particular circuit is that the **comparator gives high in the output (leg 6) when U2 > U1 and gives low when U2 < U1.**

In the case where the voltage in the not inverted input U2 to be equal with this in the inverted input U1, that is to say U2 = U1, then we have Uout = 0.

The circuit of comparator as we see functions as a simple type of converter of proportional signals to digital. For this reason the op-amp is met a lot in digital circuits, even if as we have also reported in the introduction of this course (lesson 1) the op-amp has been manufactured initially for use in analogue circuits. The use of op-amp in circuits that combine analogue and digital signals make it one of the hybrid integrated circuits.



As it has been reported previously, the voltage in the output Uout theoretically is equal to 0V, when happens U 1 = U 2 . If however in practical applications and manufactures it is essential the voltage in the output to be exactly equal to 0V when U 1 = U 2, then we should link to legs 1 and 5 a variable resistor 10 K so that we regulate micrometrically and with precision the output to 0V (see diagram).

For the comprehension of operation of op-amp and the solution of problems we can use the line of COMPARATOR of OMEGA systems OR simulate on the PC monitor circuits with the IC 741 in the Crocodile Clips program . With the use of Crocodile Clips we can draw circuits with single supply and with double, while with the line of COMPARATOR of OMEGA KIT we can experiment only with single supply.

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Lesson 1 Lesson 2 Lesson 3

Site Map

Lesson 1

By the completion of this lesson you should be able to:

- Mention the use of the op-amp
- Identify and draw the symbol of op-amp
- Identify, draw the inside view (sectional view) of IC741 and explain the operation of its legs.
- Describe and explain the main characteristics of the op-amp

THE OPERATIONAL AMPLIFIER (op-amp)

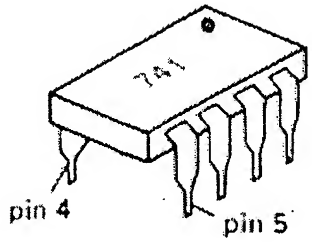
1. INTRODUCTION

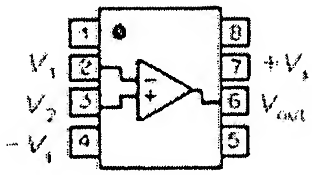
1.1 General characteristics

- The operational amplifiers are considerably integrated circuits (IC) which were used initially in the analogue computers for the achievement (performance - operation) of the mathematic calculations. This is how they took the name operational - operational amplifiers. Even if today seldom there exist analogue computers the operational amplifiers are used mainly in systems of control, in the robotics and in sound systems (stereos and Hi-Fi's).
- There exist enough microchips of operational amplifiers that differ so much in the manufacture of their sheath and their provided legs as long as and in the type of operation of/ application that is intended. For example the popular μA741 is for general use while the LF351 is an operational amplifier for systems of sound of high fidelity (Hi-Fi). In the course we will use mainly μA741.

THE PROVIDED LEGS OF μA741 AND ITS SYMBOL

- Leg 2: *Inversion input – inverting input*
- Leg 3: *Not inverting input – non*





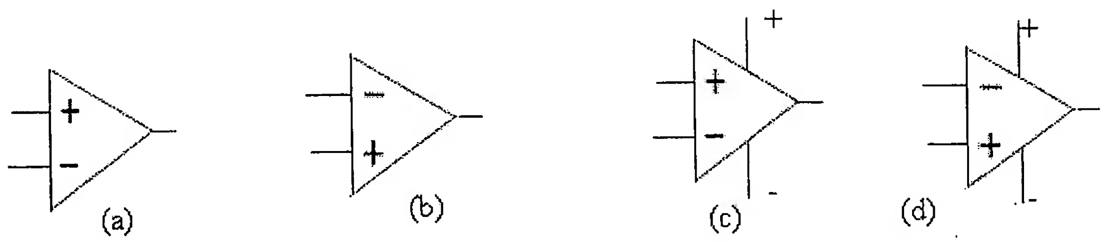
Top view

inverting input

- **Legs 4 and 7:** *Supply (-, +) 9 V*
- **Leg 6:** *Output (out)*
- **Leg 8:** *It is not used*
- **Legs 1 and 5:** *Legs of micrometric regulation of tendency of expense (in the general circuits that is usually not required a lot of precision is not used).*

Note in the above image of IC μ741 that the black dot is next to leg 1. This dot is used on the actual piece to distinguish the right side so that you can place the component correctly onto the PCB (printed circuit board) and solder it the right way up.

The most commonly used symbol of operational amplifier (op-amp) appears in (a) in the image below. Many times, depending on the design needs – you can find in use also the symbol in (b) where has been reversed the place of legs of U 2 and U 1 and the provisions of symbols (c) and (d) that present also the voltage supply of op-amp.



MAIN CHARACTERISTICS OF THE OPERATIONAL AMPLIFIER:

- It has very big input resistance Zin
- It has very small output resistance Zout
- The gain factor (or amplification magnitude) A is theoretically infinite (for μA741 is in the value of 100000)
- It can be connected as well in single supply (+ 9V, 0V) as in double (+ 9V, 0V, -9V)

BASIC CONNECTIONS OF OPERATIONAL AMPLIFIER (IS USED μA741)

1. Connected as comparator (comparator) /differential amplifier (differential amplifier) (<u>Lesson 2</u>)
2. Connected as an inverted amplifier (out of the scope of this course)
3. Connected as a non - inverting amplifier (out of the scope of this course)

Test your self whether you can:

- Mention the use of the op-amp
- Identify and draw the symbol of op-amp

- Identify, draw the inside view (sectional view) of IC741 and explain the operation of its legs.
- Describe and explain the main characteristics of the op-amp

Annex 4

EXHIBIT C

August 2000

National Semiconductor

LM161/LM361 High Speed Differential Comparators

General Description

The LM161/LM361 is a very high speed differential input, complementary TTL output voltage comparator with improved characteristics over the SE529/NE529 for which it is a pin-for-pin replacement. The device has been optimized for greater speed performance and lower input offset voltage. Typically delay varies only 3 ns for over-drive variations of 5 mV to 500 mV. It may be operated from op amp supplies (±15V).

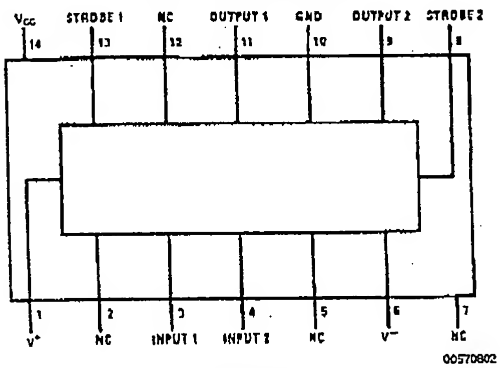
Complementary outputs having maximum skew are provided. Applications involve high speed analog to digital converters and zero-crossing detectors in disk file systems.

Features

- Independent strobes
- Guaranteed high speed: 20 ns max
- Tight delay matching on both outputs
- Complementary TTL outputs
- Operates from op amp supplies: ±15V
- Low speed variation with overdrive variation
- Low input offset voltage
- Versatile supply voltage range

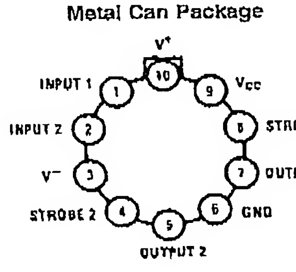
Connection Diagrams

Dual-In-Line Package



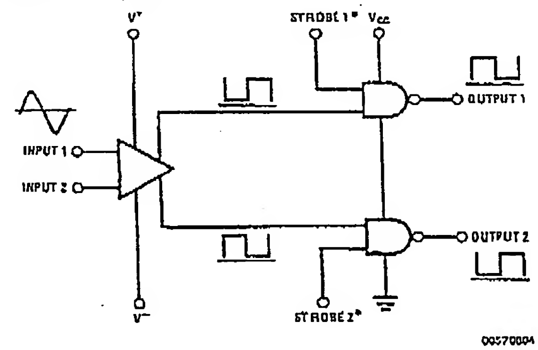
Top View
Order Number LM361M, LM361MX or LM361N
See NS Package Number M14A or N14A

Metal Can Package



Order Number LM161H/883 or LM361H
See NS Package Number H10C

Logic Diagram



*Output is low when current is drawn from strobe pin.

Annex 3

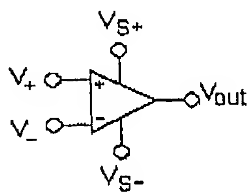
EXHIBIT D

Comparator

From Wikipedia, the free encyclopedia.

In electronics, a **comparator** is a device which compares two voltages or currents, and switches its output to indicate which is larger. More generally, the term is also used to refer to a device that compares two items of data.

A standard op-amp can be used as a comparator as indicated in the following diagram.



When the noninverting input is at a higher voltage than the inverting input, the high gain of the opamp causes it to output the most positive voltage it can. When the noninverting input drops below the inverting, the op-amp outputs the most negative voltage it can. Since the output voltage is limited by the supply voltage, for an op-amp that uses a balanced, split supply, (powered by $\pm V_S$) this action can be written:

$$V_{out} = V_S \operatorname{sgn}(V_+ - V_-)$$

where sgn(x) is the signum function.

A dedicated voltage comparator chip, like the LM339, is designed to interface directly to digital logic (such as TTL or CMOS), since the output is a binary state, and is often used to interface real world signals to digital circuitry (see: analog to digital converter). The LM339 accomplishes this with an open-collector output. When the inverting input is higher, the output of the comparator is connected to the negative power supply. When the noninverting input is higher, the output is floating (has a very high impedance to ground). With a pull-up resistor and a 0 to +5V power supply, for instance, the output takes on the voltages 0 or +5, and can be interfaced to TTL logic.

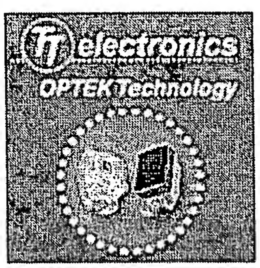
When comparing a noisy signal to a threshold, the comparator may switch rapidly from state to state as the signal crosses the threshold. If this is unwanted, a Schmitt trigger can be used to provide a cleaner output signal. It uses hysteresis to increase the switching region from a single point to a band.

Source: A previous version of this document was taken from Federal Standard 1037C.

Retrieved from "http://en.wikipedia.org/wiki/Comparator"

Categories: Electronic circuits

- This page was last modified 07:12, 24 September 2005.

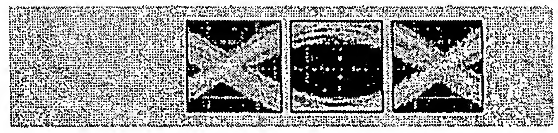


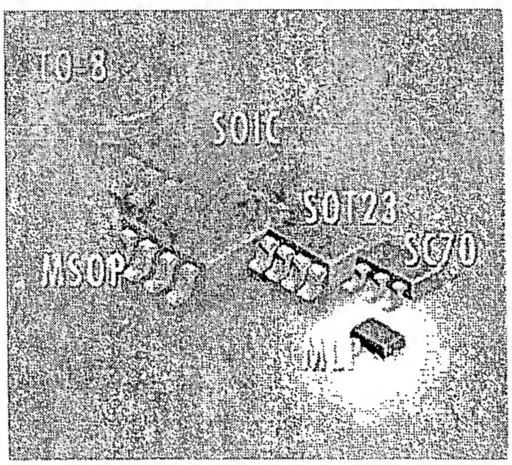
The evolution of the monolithic op amp

How to choose the best amplifier for various applications

BY DEBBIE BRANDENBURG
Fairchild Semiconductor
San Jose, CA
http://www.fairchildsemi.com

The monolithic amplifier has come a long way since its debut in 1963. Since then, amplifiers have grown to be a standard component in virtually all linear systems. Almost every major semiconductor manufacturer has amplifiers in its product portfolio.





Primarily driven by consumer applications, the industry has seen amplifiers shrink from larg metal cans to tiny 2 x 2-mm chip-scale packages. Today's amplifiers are also achieving pe levels that were unheard of in the 1960s:

* Bandwidths surpassing 1 GHz

* Slew rates soaring above 5,000 V/µs

* Supply currents dropping below 10 µA

* Supply voltage operation down to 0.9 V

* Input offset voltages below 20 µV

CMOS vs. bipolar
Advancements in process technology and leading edge design techniques have allowed IC

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manufacturers to achieve the highest performance levels. Two of the more common proces are CMOS and complementary bipolar.

There are advantages and disadvantages to designing op amps in each of these processe: Traditionally, a CMOS-designed operational amplifier has a reputation for being lower in po lower in price than one designed in a bipolar transistor process technology. Complementar amps tend to have higher bandwidth and slew rate performance than their CMOS counterp

The low-power reputation of CMOS is derived from its use in logic circuits. If the clock is no CMOS logic consumes very little power. This does not apply in bipolar amplifier circuits, wh currents must flow whether signal is applied or not.

With either process, to obtain more ac performance, you must burn more power. When it c performance versus power consumption, bipolar definitely wins the battle. The advent of S(on-insulator) and DTI (deep-trench-isolation) bipolar processes allow IC manufacturers to d high-speed amplifiers with low power consumption.

The chart in *Fig. 1* compares three bipolar amps with three CMOS amps. Care was taken i example to ensure that the amplifiers have similar specifications in order to make the comp useful.

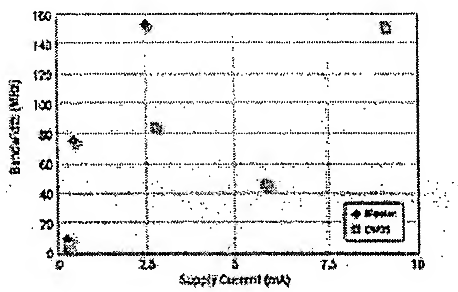

Fig. 1. The difference between bipolar and CMOS amps becomes more evide bandwidth increases.

The difference becomes more evident as bandwidth is increased. CMOS amplifiers can ac bandwidths above 150 MHz, but they typically require an increasing amount of supply curre Bandwidth level is important since power consumption is a primary concern in many applic: Designers who need high performance will naturally choose the bipolar 150-MHz amplifier around 1 mA over the more-power-hungry CMOS op amp.

The low-price reputation of CMOS actually comes from low wafer pricing due to high volum primarily by the logic world. A CMOS wafer is typically two to three times cheaper than a complementary bipolar wafer.

However, this general conception does not take die size into account. Current flow in a bip(transistor is vertical; current flow in a MOSFET is lateral. This causes a CMOS transistor to more area than a bipolar transistor with the same current capability.

Bipolar die size is usually much smaller than a comparably performing CMOS amplifier, wh the die cost to near the same level. With the advent of newer 6-in. high-yielding bipolar waf (as opposed to earlier 4 to 5-in. wafers), a much higher realized die-quantity-per-wafer is a(resulting in very competitive per die pricing when compared to CMOS (see *table*).

Design techniques

Process is not the only key factor in amplifier performance. Design techniques also play a r the last 20 years, we've seen the invention of the current-feedback (CFB) amplifier, a basic variation of the traditional voltage-feedback (VFB) type. The availability of high-speed oper: amplifiers in both CFB and VFB topologies allows design engineers to select the best ampl

or her needs.

Today's CFB and VFB amplifiers have comparable performance, but there are certain uniq advantages associated with each topology. A CFB amplifier complements an application th high slew rates, low distortion, or the ability to set gain and bandwidth independently.

A VFB amplifier, on the other hand, complements an application where low offset voltage o specifications are required. VFB amplifiers also offer more "feedback freedom," allowing nc elements in the feedback path.

Today's op amps can function as an amplifier, buffer, comparator, differential amplifier, line integrator, level shifter, peak detector, filter, photodiode amplifier, and much more. They ar to integrate more functionality, including switches and multiplexers, programmable gain ca without external resistors, and input clamps and low-pass filters for video applications.

EXHIBIT F

National Semiconductor
The Sight & Sound of Information

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COP87L88EK Product Folder

8-Bit CMOS OTP Microcontrollers with 16k Memory, Comparator, and Single-slo Capability

Generic P/N 87L88EK

General Description | Datasheet | Package & Models | Sampl & Pric

Datasheet

Title	Size in Kbytes	Date	View Online	Download	Receive via Email
COP87L88EK RK Family 8-Bit CMOS OTP Microcontrollers with 8k or 32k Memory, Comparator, and Single-slope A D Capability	507 Kbytes	13-Dec-01	View Online	Download	Receive via Email

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Package Availability, Models, Samples & Pricing

Part Number	Package			Status		Models		Samples & Electronic Orders	Budgeta Pricin	
	Type	Pins	MSL/Lead-Free Availability	LeadTimes	Quantity	SPICE	IBIS		Qty	$U ea
COP87L88EKV-XE	PLCC	44	Status	Full production 8-9 weeks	Full production 5000	N/A	N/A	Buy Now	1K+	$8.

Obsolete Parts

Obsolete Part	Alternate Part or Supplier	Source	Last Time Buy Date
COP87L88EKN-XE		NONE	03/03/2004

General Description

BEST AVAILABLE COPY

The COP87L88EK/RK Family OTP (One Time Programmable) microcontrollers are highly integrated COP8™ Feature core devices with 16k or 32k memory and advanced features including a Multi-Input Comparator and Single-slope A/D capability. These multi-chip CMOS devices are suited for applications requiring a full featured, low EMI controller with an analog comparator, current source, and voltage reference, and as pre-production devices for a masked ROM design. Lower cost pin and software compatible 8k ROM versions (COP888EK) are available for use with a range of COP8 software and hardware development tools.

Family features include an 8-bit memory mapped architecture, 10 MHz CKI (-XE = crystal oscillator) with 1 μs instruction cycle, three multi-function 16-bit timer/counters with PWM, MICROWIRE/PLUS™ serial I/O, one analog comparator with seven input multiplexor, an analog current source and $V_{CC}/2$ reference, two power saving HALT/IDLE modes, idle timer, MIWU, high current outputs, software selectable I/O options, WATCHDOG™ timer and Clock Monitor, 2.7V to 5.5V operation and 28/40/44 pin packages.

Devices included in this datasheet are:

Device	Memory (bytes)	RAM (bytes)	I/O Pins	Packages	Temperature
COP87L84EK	16k OTP EPROM	256	24	28 DIP/SOIC	-40 to +85°C
COP87L88EK	16k OTP EPROM	256	36/40	40 DIP, 44 PLCC	-40 to +85°C
COP87L84RK	32k OTP EPROM	256	24	28 DIP/SOIC	-40 to +85°C
COP87L88RK	32k OTP EPROM	256	36/40	40 DIP, 44 PLCC	-40 to +85°C

[Information as of 11-Sep-2003]